THE LAST MILLION YEARS AROUND LAKE KEILAMBETE, WESTERN VICTORIA

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Pollen records from sediments preserved in the older volcanic crater maars of Lake Terang and Pejark Marsh, situated close to the more recent and intensively researched younger maar containing Lake Keilambete, provide a basis for understanding the development of the present landscape of western Victoria in relation to past vegetation evolution, climate change and volcanic activity. Despite dating uncertainties and discontinuities, the record from Lake Terang may cover much of the last five hundred thousand years (500 ka) while that from Pejark Marsh is fission track dated to between about one million years (1 Ma) and 700 ka. An analogue method is used to provide measures of past vegetation and precipitation. Overall, the Early Pleistocene vegetation was dominated by herbaceous taxa with an open canopy of trees composed of more *Callitris* and fewer eucalypts than today. The climate was drier, never achieving rainfall levels higher than present. Since this time the vegetation and climate displayed greater variability, probably in relation to global shifts between glacial and interglacial conditions, with interglacial peaks often showing the development of eucalypt forest and expansion of cool temperate rainforest. Through the whole period, climate appears to have been the dominant influence on vegetation with no detectable impact of volcanic activity.

Key words: Quaternary, pollen analysis, palaeoclimates, analogue matching, volcanic plains, Victoria

LAKE Keilambete has been a major focus of palaeoenvironmental research for over 30 years. Past lake and salinity records derived from the study of sediments (Bowler 1981; Bowler and Hamada 1971), ostracodes (De Deckker 1982), ostracod chemistry (Chivas et al. 1993; 1985) and aquatic pollen (Dodson 1974) and hydrological modelling based on the calibration of these records (Jones et al. 1998), have combined to provide an unprecedented, high resolution record of effective precipitation over approximately the last 10,000 years (the Holocene period) in Australia. Calculated precipitation/evaporation ratios varied from less than 0.7 around 10,000 years ago when the lake was dry to at least 1.1 about 7000 years ago when the depth of the lake reached 40 m and overflowed (Jones et al. 1998). Presently the lake is at an intermediate level but, like many lakes within the region, the level has been falling rapidly in the last 100 years, probably due to a combination of reduced precipitation and increased temperatures (Jones et al. 1998).

In contrast to the marked changes in environmental indicators derived from the lake basin, the pollen record of terrestrial vegetation from this site is bland (Dodson, 1974; Tibby et al. this volume). The domination by Poaceae with consistently low levels of *Eucalyptus* and Casuarinaceae through the whole of the last 10,000 years, indicates a little varying open woodland, apparently insensitive to the substantial changes in climate. Both the lack of variation in regional vegetation through time and the absence of forest at the present day have been the subject of some debate as elucidated by Dodson (1974) and Jones (2001). A mean annual rainfall of about 800 mm, and substantially more during the mid Holocene, is adequate to support sclerophyll forest vegetation throughout much of southeastern Australia and, consequently, other factors such as soil and fire have been proposed as limiting forest development. Certainly the heavy clay soils derived from some basalt parent material are not conducive to tree growth due to swelling and shrinking of clay minerals and poor drainage capacity (Dodson 1974). Sclerophyll forests may also be less competitive on such substrates, having evolved on much older soil landscapes. However, very recent, little weathered basalt flows do support forest, most likely because of their coarse, well drained, structure. Fire, on its own, is unlikely to have resulted in the exclusion of forest as this factor is an integral component of most forest systems in Australia.

A greater understanding of the nature of the vegetation around Lake Keilambete and its relationship to soils, fire and climate can perhaps be gained by a longer term history of vegetation and environments. Although evidence of past environmental conditions from Lake Keilambete itself, prior to the Holocene, is very limited and does not include pollen data (Bowler and Hamada 1971), other nearby crater lakes, geologically older than Lake Keilambete, have recently revealed much longer records. Here we present evidence of vegetation and environmental change from Lake Terang and Pejark Marsh that together are considered to cover much of the last million years, a significant portion of the lifetime of the volcanic province. Details of the record from Pejark Marsh are contained in Wagstaff et al. (2001) while the more recent part of the record from Lake Terang is presented in D'Costa and Kershaw (1995). The whole of the existing Terang record formed the MA thesis of D'Costa (1989) but uncertainty over its chronology has discouraged formal publication. A Holocene pollen record from Lake Keilambete is contained in Kershaw, Tibby et al. (this volume).

THE PALAEOECOLOGICAL SITES AND THEIR REGIONAL SETTING

Lake Keilambete, Lake Terang and Pejark Marsh lie within 2-4 kilometres of each other around the town of Terang (Fig. 1). All originated as maar craters formed by explosions resulting from rising magma coming into contact with ground water within the Tertiary sedimentary limestone rocks, underlying the basalt (Birch 1994). The basins filled with water and acted like natural rain gauges, with sediments and biological indicators reflecting variation in lake water level and hence effective precipitation. Lake Keilambete still acts as a rain gauge lake but Lake Terang was drained by early European settlers and sediment infilling converted Pejark Marsh from a lake to a swamp a long time prior to subsequent drainage by Europeans. The Lake or 'swamp' surfaces of the sites all lie between 100 and 140 m ASL, only slightly lower than the general landscape that is relatively flat apart from volcanic structures such as Mt Noorat and Mount Terang, the former reaching above 250 m ASL (Fig. 1).

The area experiences a temperate climate with warm summers and a winter rainfall maximum. Rainfall averages 800 mm with 260 mm falling in winter. Mean annual temperature is around 13^0 C with means of about 9^{0}C and 18^{0}C for the coolest and warmest months respectively. The regional open *Eucalyptus* woodland with a grassy ground layer that existed at the time of European arrival was interrupted by a mixed woodland of *Allocasuarina verticillata, Banksia marginata* and *Acacia* in better drained areas, particularly scoria cones, that could have included Mts. Noorat and Terang, and scrub dominated by *Leptospermum lanigerum* in swamps such as that of Pejark Marsh. More distant, eucalypt open forest occurs on recent basalt 'stoney rise' country and on sedimentary parent materials within and around the basalts, while tall open eucalypt forest and patches of cool temperate rainforest dominated by *Nothofagus* are found in the Otway Ranges to the southeast, where rainfall can exceed 1500 mm per annum.

FIELD, LABORATORY AND NUMERICAL METHODS

Pejark Marsh is geomorphologically old with the original lake having filled with sediment and the tuff ring, that would have surrounded the crater, having virtually eroded away. A core was extracted from the swamp surface by the Geological Survey of Victoria in 1991 to a depth of 99 m. This core encountered lake sediments, peats and volcanic ashes above basal marl of Tertiary age, the latter preserved below the explosive maar structure. Unfortunately the construction of a continuous record from the sediments of the lake basin has been prevented by failure to recover all core material. The sequence is capped by a volcanic ash deposit that is likely to have helped prevent erosion or oxidation of the underlying sediments.

Fig. 1. Location of study sites

Lake Terang is geomorphologically much younger than Pejark Marsh with a well-preserved tuff ring and still contained shallow water at the time of European settlement. Initial analyses were undertaken on samples collected from a 20 m core taken from the centre of the drained lake by the Australian National University in 1985. The record was extended subsequently from cores taken from a similar location by Monash University in 1987. One core focused on the topmost sediments that were not adequately sampled originally while the other core reached to 38 m although it failed to penetrate to the base of the contained lake and swamp sediments.

Samples from available lake and swamp material in both cores were taken at 20 cm intervals for pollen and charcoal analysis and processed by standard procedures (Moore et al. 1978). Either a minimum of 200 pollen grains from terrestrial vegetation per sample (Terang) or the total number of pollen from one whole microscope slide per sample (Pejark) was counted where pollen was preserved. All charcoal particles with a diameter of greater than 10μm were counted as a measure of past fire activity. As charcoal values were calculated using slightly different techniques in the two records (at Lake Terang as the concentration of particles per sample and at Pejark Marsh as the area of charcoal per sample) values were standardised by dividing the values in each record by their maximum value.

For this study, emphasis is placed on those pollen taxa that have been demonstrated to reflect variation in regional vegetation of southeastern Australia (Kershaw et al. 1994; D'Costa and Kershaw 1997). They include the woody plants *Eucalyptus* and Casuarinaceae as the dominants of sclerophyll forest and woodland, *Acacia*, *Banksia* and *Dodonaea* as other notable and widespread woody representatives of sclerophyll vegetation, *Pomaderris* (specifically the *P. aspera/apetala* pollen type) that characterizes the understorey of many tall open forest communities and *Nothofagus*, *Podocarpus*, *Phyllocladus* and *Lagarostrobos* that typify cool temperate rainforest and scrub in Victoria and more especially in Tasmania. They also include Poaceae, Asteraceae and native *Plantago* that predominantly form the understorey of open sclerophyll forests and woodlands but, in the case of the first two mentioned taxa, can dominate treeless communities such as grasslands and herbfields under extreme environmental conditions. These form the pollen sum on which all percentages for each sample in the constructed pollen diagrams (Figs. 2 and 3) are based.

Additional taxa that contribute to a general picture of regional vegetation include Chenopodiaceae, *Callitris*, Araucariaceae, *Cyathea/Dicksonia*, but each is excluded from the pollen sum for different reasons; Chenopodiaceae because saltbushes may sometimes dominate local saline swamps; *Callitris* because its delicate and indistinctive pollen may not always be recognized and recorded, at least in some sediment types; Araucariaceae because it no longer occurs in southeastern Australia and therefore, although of potential stratigraphic and palaeoclimatic value, is absent from modern comparative data; and *Cyathea/Dicksonia* because they have spores rather than pollen that may have different dispersal characteristics. It is also very possible that components of *Cyathea*, like Araucariaceae, have disappeared from the landscape in relatively recent times providing a no analogue situation. The same may apply to one component of Asteraceae that produces blunt rather than sharp spined pollen grains (Asteraceae type b). There is uncertainty as to whether there are extant parent plants that could have given rise to Asteraceae type b pollen that is recorded predominantly in glacial-aged sediments (Macphail and Martin 1991).

An estimate of mean annual rainfall (RANN) for each point in time represented by a pollen spectrum was calculated by analogue matching (Overpeck et al. 1985). The methodology followed that detailed in Penny et al. (this volume). Essentially, each fossil pollen spectrum was compared with recent (pre-European) pollen spectra from a collection of sites in southeastern Australia (Kershaw et al. 1994; D'Costa and Kershaw 1997) for which rainfall estimates had been derived from BIOCLIM (Busby, 1991) using the dissimilarity measure, squared chord distance (d^2), and the pollen sum taxa. The estimated RANN for each fossil spectrum is the weighted average of RANN in the three sites with lowest squared chord distance.

The pollen sum taxa were also used as the basis for a stratigraphically unconstrained classification of all fossil pollen spectra from the two sites, undertaken to characterize the range and types of vegetation represented and to see if there were systematic differences between the spectra from the two cores. Bray-Curtis similarity was calculated on the untransformed relative abundances of taxa in the south-east Australian pollen sum (D'Costa and Kershaw 1997) in PRIMER for windows v. 5.2.7 (Clarke and Gorley 2001). A similarity value of 70% was used as a cut off to define the groups shown in Figs. 2 and 3.

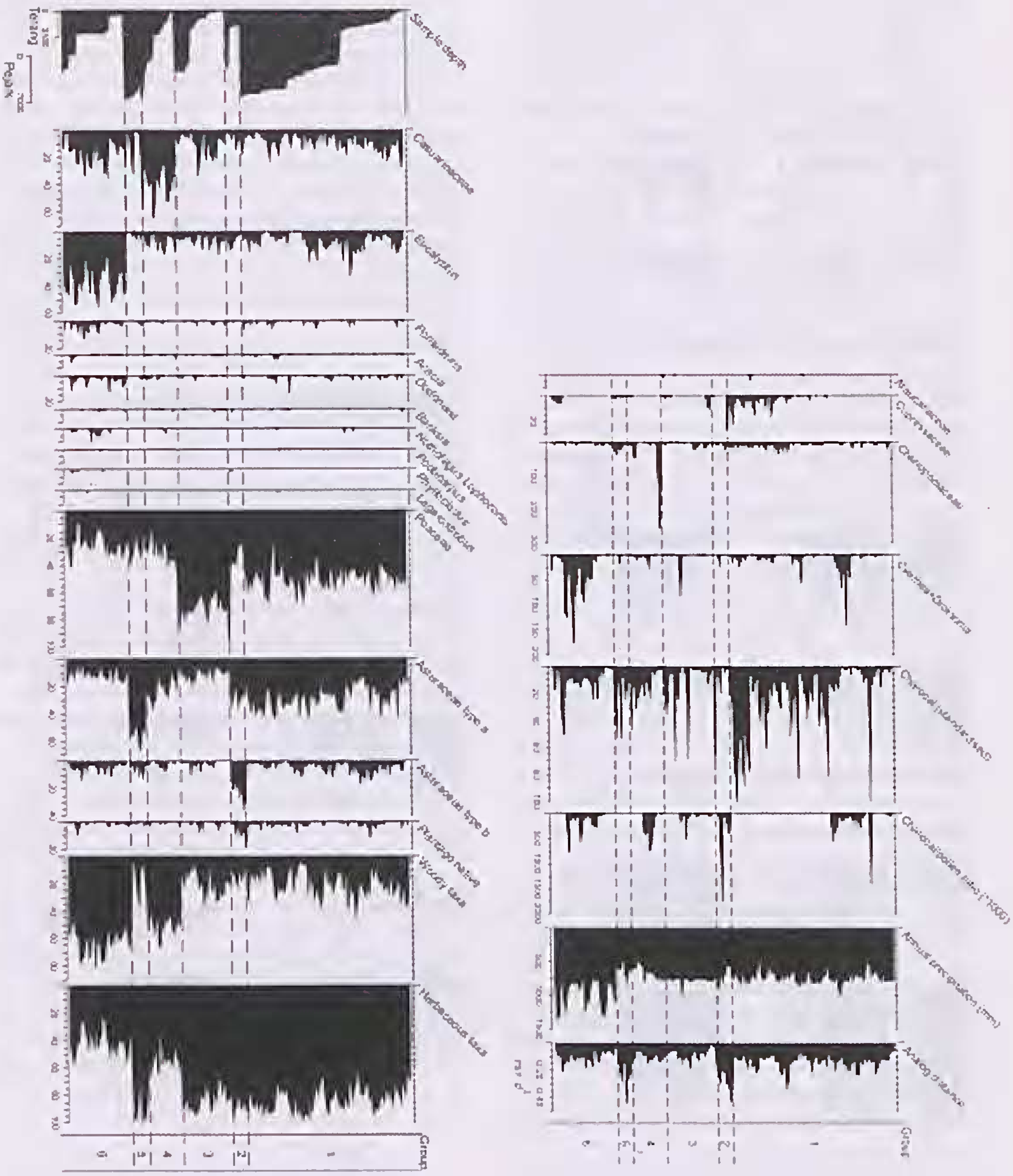

Fig. 2a and b. Pollen spectra from Lake Terang and Pejark Marsh grouped according to Bray-Curtis similarity rather than stratigraphic position. Pollen taxon values are expressed as percentages of the common taxon pollen sum of the appropriate sample. Precipitation estimates are derived from comparison of fossil spectra with precipitation values of closest modern pollen samples. Charcoal values are standardized in relation to maximum values for both records.

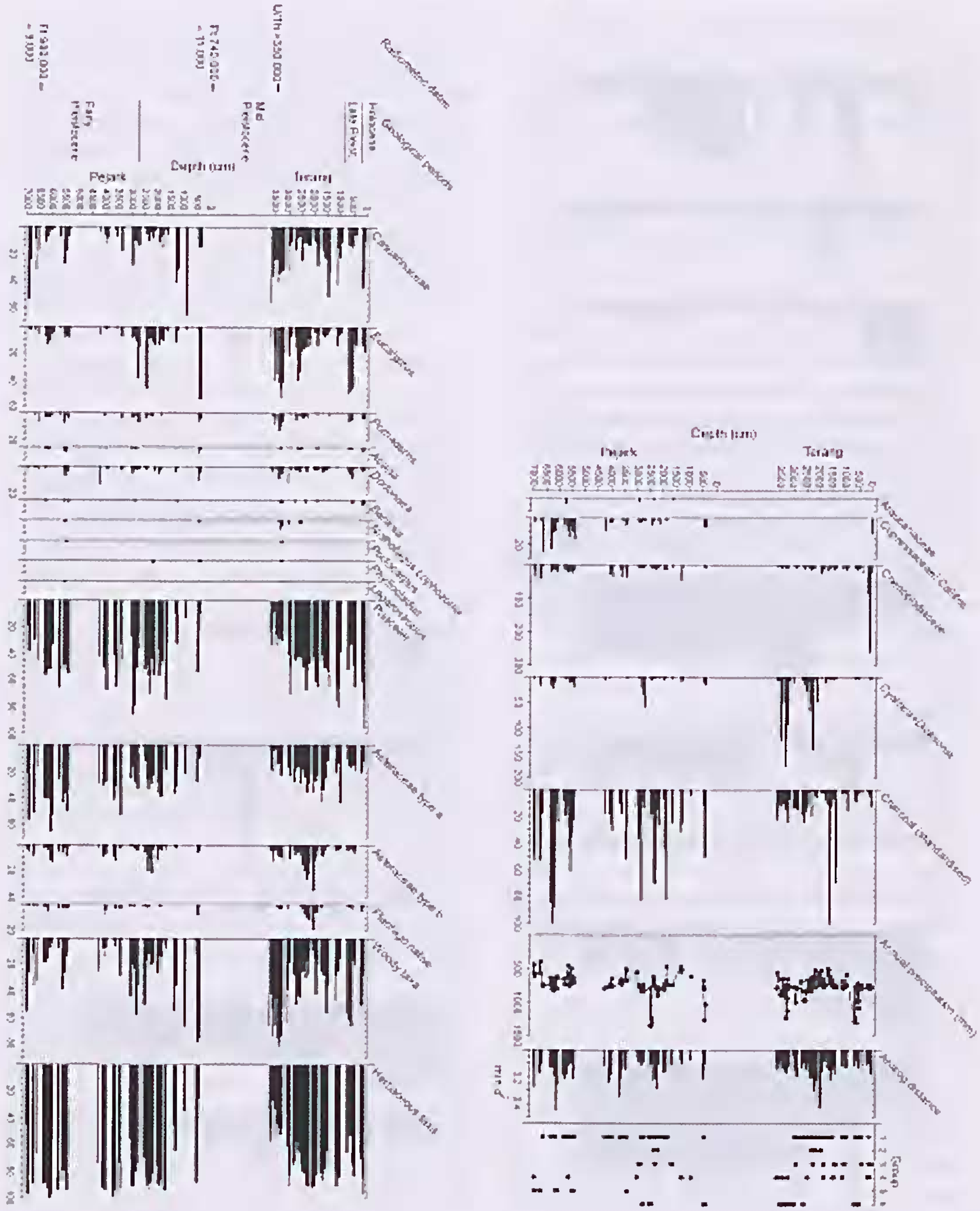

Fig. 3A and B. Pollen spectra from Lake Terang and Pejark Marsh stratigraphically ordered in relation to depth below swamp surface for individual sites. Pollen taxon values are expressed as percentages of the common taxon pollen sum of the appropriate sample. Precipitation estimates are derived from comparison of fossil spectra with precipitation values of closest modern pollen samples. Charcoal values are standardized in relation to maximum values for both records. Groups are those derived from the stratigraphically unconstrained classification of spectra as shown in figure 2.

Accurate dating has been, and continues to be, a major problem with long records. Research into these older sediment sequences was delayed for many years because of a lack of suitable radiometric dating methods beyond the limit of radiocarbon dating, somewhere between 30,000 and 55,000 years BP. Early radiocarbon dates did indicate that most of the Lake Terang sequence was probably beyond this limit (Alan Chivas pers. comm.) and that the whole of Pejark Marsh was beyond the limit. Uranium/thorium dating was undertaken on lake sediment from close to the base of Lake Terang and from close to the top of Pejark Marsh as part of a more general program incorporating the dating of long Australian palynological records by the Australian Nuclear Science and Technology Organisation and several universities. Although most of this research is not yet published, results from the Western Plains site of Lake Wangoom (Harle et al. 1999; 2002) provide some confidence in general age estimation from a sequence of dates derived from Western Plains organic sediment, but they also demonstrate that individual dates have to be treated with a great deal of caution. The methodology is detailed in these papers.

Ash bands in the Pejark core were examined for their potential for zircon fission track dating. Two samples were successfully dated by this method (see Wagstaff et al. 2001 for methodology), one from close to the base of the sequence and the other from the ash capping the sequence.

Approximate timescales for the sequences are provided from the few available radiometric dates and by comparison of patterns of change in pollen and precipitation with those in the marine oxygen isotope stratigraphy (MIS) of Shackleton et al. (1990) (see Wagstaff et al. 2001; and Urban et al. 1996; for the Pejark and Terang chronologies respectively). The validity of this procedure depends upon the relationships demonstrated between Western Plains pollen records and the MIS stratigraphy over the last one or two glacial cycles (Harle et al. 1999; 2002) having been maintained over the whole of the later part of the Quaternary period.

RANGE OF VEGETATION AND ENVIRONMENTS REPRESENTED

Six major groups emerged from the classification of pollen spectra. The groupings form the basis of Fig 2, with spectra ordered stratigraphically within each group. Based on available evidence, the whole of the Pejark sequence is older than that of Terang and therefore the samples from this site are shown, in stratigraphic position, below those of Terang within each group. Terang spectra cover the depth of samples from 0 cm (the sediment surface) to 3650 cm while Pejark spectra extend from 350 to 7000 cm. Some indication of associated environmental conditions can be gauged from RANN estimates and charcoal values.

Group 1 is the largest and appears to cover spectra that are geologically young, back to nearly the oldest. The vegetation was open with a predominance of herbaceous taxa within which both Poaceae and Asteraceae (generally containing and Asteraceae type b component) were well represented. Casuarinaceae and *Eucalyptus* are the major woody taxa though they seldom have greater than 20% representation. *Pomaderris* and *Dodonaea* are conspicuous while *Acacia* is poorly represented, as it is through almost the whole record, except for a one small group of samples, close to the base of the sequence. Of the taxa outside the sum, Chenopodiaceae is consistently present, with relatively low values in the younger spectra and consistently higher values in the older spectra. A similar, but more exaggerated pattern is shown by *Callitris* that is virtually absent in younger samples yet abundant in older ones. The tree fern spores have erratic representation (as they do through the whole diagram) with high values tending to occur in small clumps. Inferred rainfall generally varies from present day values of about 800 mm down to about 500 mm, matching the lowest rainfall levels recorded on the basaltic plains today, while charcoal levels, although variable, probably indicate greater burning in this type of vegetation than in any other.

Group 3 also indicates the regional presence of open woodland. It is distinguished from group 1 by exhibiting relatively higher values for Poaceae and relatively lower values for Asteraceae, including Asteraceae type b. It is represented in both sequences although is not present in the older part of the Pejark Marsh sequence. Inferred rainfall levels are remarkably consistent, around 750 to 800 mm, very similar to those of today. In fact the high Poaceae values are consistent with the domination of the plains vegetation by grassy woodland. The lack of group 3 spectra in the oldest part of the record suggests that this assemblage may have developed relatively recently.

Two other small groups display high percentages of herbaceous taxa, group 2 that is composed of spectra having highest Asteraceae type b percentages and generally highest percentages of *Plantago,* and group 5 that has the largest values of Asteraceae type a. Poaceae values are surprisingly low in both groups. The low rainfall estimates are consistent with what were likely to have been both cool and dry conditions. It is difficult to suggest what was responsible for the differences between these groups, especially as Asteraceae type a features so prominently and that these groups have the highest minimum d^2 values, indicating poor present day analogue matches.

Only two groups are dominated by pollen of woody taxa. Group 4 is charactersied only by high values of Casuarinaceae and there is no positive response in any other woody taxa within the sum. The group contains by far the highest value of Chenopodiaceae but this is not supported by higher values overall. Despite the high woody values, estimated rainfall is lower than for most other groups. Rainfall estimates generally increase through time suggesting a gradually changing assemblage and possibly an evolving vegetation type. Group 6 is dominated by *Eucalyptus* and represents sclerophyll forest with highest values for *Pomaderris, Nothofagus* and tree ferns together with most occurrences of the minor cool temperate rainforest taxa, indicating high rainfall. This is borne out by rainfall estimates that reach about 1300 mm and do not fall below 750 mm. This assemblage is best represented in more recent spectra and is not recorded at all in the oldest spectra.

CORE SEQUENCE CHRONOLOGIES

The combined record from the three Lake Terang cores and the Pejark Marsh core are shown on Fig. 3. The Terang component of the record is positioned above that of Pejark Marsh to illustrate its relative youth.

The top part of the Terang pollen sequence is discontinuous due to an absence of pollen in some sections, presumably because conditions were too dry to allow pollen preservation. The top set of pollen samples are radiocarbon dated to Holocene, while the set below them can be correlated with spectra of MIS 5 (last interglacial) age from Lake Wangoom. Consequently, it appears that there is no evidence preserved of the last glacial period. The time scale of the remainder of the Terang sequence is uncertain. There are two more phases lacking pollen that may represent glacial or stadial conditions, and indicate that the base of the sequence may be some antiquity. The suggestion of a relatively old age is supported by the date of > 350 ka from the U/Th date near the base of the sequence. It is proposed that the basal phase of the Terang sequence with its high woody plant values could well correspond to MIS 11 (dating to 360-425 ka), which is considered globally to be the most pronounced interglacial period.

The spasmodic presence of Araucariaceae through the Pejark sequence is indicative of the relative antiquity of this sequence compared with Lake Terang, a suggestion confirmed by the two fission track dates from Pejark which indicate that the sequence could range in age from about 1000 ka to 740 ka. Attempted correlation of variations in the pollen record with those in the orbitally-tuned marine oxygen isotope record of Shackleton et al. (1990) suggests that the age range might be somewhat greater, from about 1030 to 680 ka embracing MIS 17 to 30 (Wagstaff et al. 2001), but this correlation is fraught with uncertainty, especially as core recovery was so discontinuous.

More certainty about the antiquity of Pejark relative to Terang could be obtained by analysis of the composition of the tuff layers evident within the cores, especially that capping the Pejark Marsh sequence. Walcott (1919) undertook an investigation of the surrounding volcanic vents, i.e. Mount Noorat, Lake Keilembete and Lake Terang in an attempt to determine the source of this capping ash. Although all have an associated tuff ring and any of them could have been the source of the ash, he considered that Lake Terang was the most likely source as, from excavations and wells dug between Pejark Marsh and Lake Terang, the tuff was present in every excavation and increased in thickness towards Lake Terang. This suggested association remains to be tested but it is consistent with existing dates. It also suggests that, if a core was taken to the base of the Lake Terang sediments, the missing period between the two records could be almost fully filled.

PATTERNS OF VEGETATION AND ENVIRONMENTAL CHANGE

Regardless of the uncertainties regarding the ages and degree of continuity of the sequences, a general picture emerges of vegetation and environmental changes through the last million years from the proxy data. There is a great deal of variability in the pollen data, which, at this scale, is most likely dominated by Milankovitch-forced glacial-interglacial cyclicity.

The basal part of the Pejark sequence, to about 30 m, is the least variable for many taxa especially *Eucalyptus*, and this low level of variability is reflected in the pollen assemblage groups with only three (1, 4 and 5) recorded. As noted previously, group 5 is restricted to this period and may well represent the last phases of a vegetation type, dominated by Asteraceae type a, which no longer exists. Group 1 spectra are also distinct within this group as a whole in that *Callitris*, rather than *Eucalyptus* or Casuarinaceae, is the major woody taxon, although high values for Casuarinaceae are characteristic of group 4 spectra. The lack of spectra from group 6 suggests that reduced variation is the result mainly of relatively dry conditions and this is supported by inferred precipitation that ranges only between about 400 and 800 mm. This dampened variability is consistent with global evidence for low amplitude oscillations dominated by the 40 ka obliquity orbital signal in the Early Pleistocene (c 1.8 – 0.8 Ma) and extending into the Early-Middle Pleistocene transition (Shackleton et al. 1990).

The change to greater environmental variability in the Middle Pleistocene, as a result of higher peaks in woody plant pollen values, is also marked by higher values for *Eucalyptus* suggesting the development or expansion of sclerophyll forests as opposed to woodlands within the region. The disappearance of Araucariaceae (presently restricted in Australia to rainforests in the northeastern part of the continent – apart from wollemi pine that possesses a different and distinct pollen type), that had been an important component of southeast Australian vegetation during the Pliocene (Macphail, 1997), may seem inconsistent with a general increase in precipitation. However, the Araucariaceae have their greatest development in drier rainforest and it may be that increased variability, perhaps in combination with altered seasonality, rather than dryness, was the major influence on their demise (Kershaw and Wagstaff 1991). Any alteration of fire regimes may well have also been important because of the fire sensitivity of component taxa, although there is no evidence of increased burning from the charcoal data. In fact, charcoal values are generally lower within the Terang sequence, but this may be an artifact of standardization of the charcoal record.

Characteristically high amplitude, low frequency oscillations are demonstrated for the Terang and for the Pejark sequence above the Lower Pleistocene/Middle Pleistocene boundary by occasional 'interglacial' peaks in the eucalypt forest assemblage of group 6, where rainfall at times is estimated to have exceeded 1250 mm. These rainfall values have been clearly influenced by regional expansions of wet sclerophyll forest and cool temperate rainforest indicated by notable values of *Pomaderris* and *Nothofagus*, respectively. As these expansions may have been largely confined to the Otways rather than extending over the Western Plains, the inferred rainfall values for the pollen sites may be exaggerated.

In contrast to peak rainfall during interglacials, there are no deep rainfall troughs during glacial periods. However, the emergence of group 2 samples, with high Asteraceae type b and *Plantago* values, may indicate glacial extreme conditions, with low temperatures perhaps compensating any rainfall lowering. It is interesting that this group disappears towards the top of the Terang sequence, most likely due to the lack of pollen preservation within drying lake sediments.

DISCUSSION AND CONCLUSIONS

The reconstruction of this record of past vegetation and environments around Lake Keilambete has, despite major gaps and dating uncertainties, provided an interpretable picture of past conditions. It is one of the few records from terrestrial sedimentary environments to cover the last million years. Consequently the record does have global as well as local significance, a feature illustrated by the importance of Milankovitch forcing on the recorded variations and changes in both climate and vegetation.

The record provides some useful insights into the evolution of the present vegetation. The occurrences of Araucariaceae pollen in the early part of the record most likely indicate the remaining remnants of drier rainforest that was widespread in southeastern Australia during the Late Cenozoic, including at least parts of the Western Plains during the Lower Pliocene (MacPhail, 1996). The demise of this vegetation and probably also *Callitris* communities (Jones, 1998) may have resulted from the extreme, particularly cold and dry, conditions that characterized subsequent Middle Pleistocene climates. Increased climatic variability, by contrast, is likely to have facilitated the spread of eucalypt-dominated communities, especially during warm-wet 'interglacial' periods. It is notable that eucalypt expansion has been much greater than that of the associated woody taxa *Dodonaea*, *Pomaderris* and *Acacia* suggesting the development of 'new' eucalypt community types. In contrast to the demise of dry rainforest, cool temperate rainforest remnants containing taxa such as *Nothofagus cunninghamii* and particularly *Cyathea* survived and even expanded during favourable conditions. Trace values for the present day cool temperate rainforest Tasmanian endemics *Phyllocladus* and *Lagarostrobos* may indicate that these taxa also survived well into the Middle Pleistocene in western Victoria. Conversely, the pollen may have derived by wind-transport from Tasmanian forests. However, it has been established that *Phyllocladus* at least was present in the Otway Ranges during the early part of the last glacial/interglacial cycle (McKenzie and Kershaw 2000).

In relation to the question of apparent insensitivity of the vegetation around Lake Keilambete to Holocene changes in climate, this extended record certainly demonstrates that the vegetation has changed dramatically within the region, apparently in response to climate change. Even during the Holocene there is significant vegetation change in the area. Although Poaceae is dominant and *Eucalyptus* values are generally low, indicating the regional presence of an open woodland vegetation, values for Casuarinaceae are high, up to 40% in the early Holocene, falling to less than 10% in the late Holocene. This degree of change, which is not evident in the Lake Keilambete record, might be explained by an early Holocene colonisation of the scoria cones around Terang and their subsequent contraction due to factors such as fire and increasingly impeded drainage as rainfall increased. The lack of vegetation response around Keilambete could then be explained by the lack of relief within its vicinity. In general terms, the variability around both Terang and Pejark in the past might be a result of local topographical and soil variability providing suitable habitat for a range of community types, whereas the flat plain around Keilambete did not allow the development of such diversity.

If it is the case that local vegetation distributions were having such an influence on pollen assemblages derived from the centre of large lake basins, it is very possible that the indicators of tall open forests and rainforests might also have similarly local signatures and did expand onto the Western Plains during interglacial periods or expanded from small pockets on the plains during these times. It seems improbable that *Nothofagus*, with its limited dispersal ability (Howard 1973), was able to freely move on and off the plains or was able to survive on the plains through the recorded period under such low and variable rainfall. Consequently, this suggestion of a pollen response to very local influences has to be treated with some caution.

Even though the Holocene record from Lake Terang shows a great deal more variation than that from Lake Keilambete, and covers three assemblage groups, the inferred rainfall does not indicate significant change, nor is there any representation of the group 4 assemblage as there is in some previous interglacials. It is possible that the vegetation and perhaps, as a result, also the climate have been systematically altered since the Last Interglacial period. It has been suggested that the impact of people, with their arrival at some time during the last glacial period, resulted in increased burning and a change to more open or sclerophyllous vegetation (see Kershaw et al. 2002; for an Australian overview and Jones 1998; for a Western Victorian perspective). Unfortunately there is no evidence of the last glacial period in this record to determine the existence or nature of any transitions (but see Harle et al. this volume). Certainly there doesn't seem to have been any major change in charcoal values, although no clear relationship between charcoal and fire regime has been established (Kershaw et al. 2002). Although there may have been significant regional reductions or extinctions in some taxa and human impact through burning may have been involved, the weight of evidence suggests that fire has been a conspicuous feature of the environment for a long period of time and there was no major human-induced landscape 'transformation' in southeastern Australia.

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